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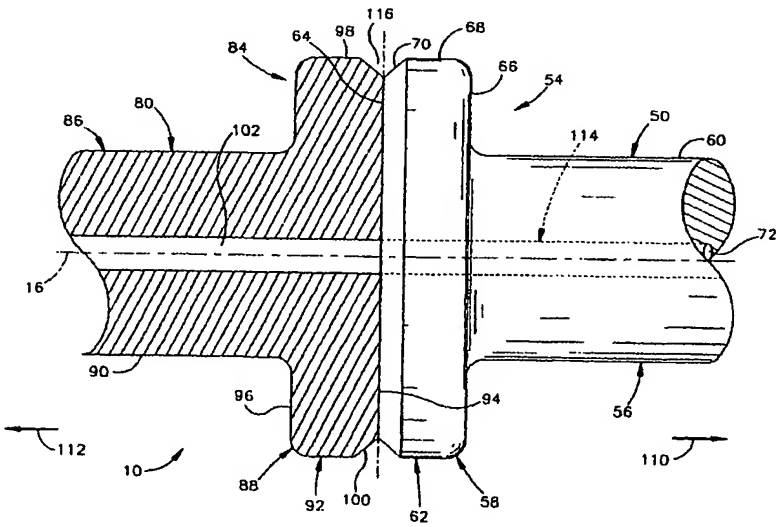
(54) Title: RACK WITH INTEGRAL PISTON FOR HYDRAULIC POWER ASSIST RACK AND PINION STEERING SYSTEM



(57) Abstract: A hydraulic power assist rack and pinion steering system (12) for a vehicle inleudes a housing (14) in which a rack (10) is movable along an axis (16) to effect turning movement of steerable wheels of the vehicle. The rack (10) comprises a first rack part (50) having an elongate body portion (56) and an end portion formed as a first piston portion (58), and a second rack (80) part having an elongate body portion (86) and an end portion formed as a second piston portion (88). The first piston portion (58) of the first rack part (50) is joined to the second piston portion (88) of the second rack part (80) to form a piston (22). The body portion (56) of the first rack part (50) extends axially away from the piston (22) in a first direction (110). The body portion (86) of the second rack part (80) extends axially away from the piston (22) in a second direction (112) opposite the first direction (110).

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RACK WITH INTEGRAL PISTON FOR HYDRAULIC POWER ASSIST RACK AND PINION STEERING SYSTEM

Background of the Invention

Technical Field

The present invention relates to a rack for a hydraulic power assist rack and pinion steering system, and to method of forming a rack.

Description of the Prior Art

U.S. Patent No. 5,890,394 describes a hydraulic power assist rack and pinion steering system for a vehicle. The system includes a rack movable to effect turning movement of steerable wheels of the vehicle. Flexible boots are mounted on each end of the rack. A breather hole extending longitudinally through the rack allows the boots to communicate with each other to maintain pressure equilibrium so that neither boot collapses or is subjected to excessive expansion.

Japan Published Application No. 04294929 shows a piston rod for a power steering unit formed by joining two

rod pieces end to end and enlarging their diameters at the point of joinder to form a piston.

Summary of the Invention

The present invention relates to a rack for a hydraulic power assist rack and pinion steering system for a vehicle having steerable wheels. The system includes a housing in which the rack is movable along an axis to effect turning movement of the steerable wheels of the vehicle. The rack comprises a first rack part having an elongate body portion and an end portion formed as a first piston portion, and a second rack part having an elongate body portion and an end portion formed as a second piston portion. The first piston portion of the first rack part is joined to the second piston portion of the second rack part to form a piston. The body portion of the first rack part extends axially away from the piston in a first direction. The body portion of the second rack part extends axially away from the piston in a second direction opposite the first direction.

The present invention also relates to a method of forming a steering gear rack. The method comprises the steps of forming a first blank into a first rack part having a radially extending end portion; forming a second

blank into a second rack part having a radially extending end portion; and, thereafter, attaching the radially extending portion of the first rack part to the radially extending portion of the second rack part to form an integral steering gear rack.

Brief Description of the Drawings

The foregoing and other features of the present invention will become apparent to one skilled in the art to which the present invention relates upon consideration of the following description of the invention with reference to the accompanying drawings, in which:

Fig. 1 is an elevational view, partly in section, of a hydraulic power assist rack and pinion steering system including a rack and piston in accordance with a first embodiment of the present invention;

Fig. 2 is an enlarged view of a portion of Fig. 1 showing the piston; and

Figs. 3 and 4 are views illustrating a method of forming a portion of the rack of Fig. 1.

Detailed Description of the Invention

The present invention relates to a rack for a hydraulic power assist rack and pinion steering system, and to a method of making a rack. The present invention

is applicable to various rack designs for hydraulic power assist rack and pinion steering systems. As representative of the present invention, Fig. 1 illustrates a rack 10, which forms a part of a steering system 12.

The steering system 12 includes a housing 14. The rack 10, described below in detail, is supported by and is movable relative to the housing 14 along an axis 16. Opposite ends of the rack 10 are connected by suitable linkage 18, such as tie rods, with steerable wheels (not shown) of the vehicle. At opposite ends of the rack 10, two flexible boots 20 seal the connections between the rack and the steering linkage 18. Upon axial movement of the rack 10 relative to the housing 14, the steerable wheels of the vehicle are turned in a known manner.

The steering system 12 includes a hydraulic motor 21 for assisting the vehicle operator in turning the steerable wheels of the vehicle. The hydraulic motor 21 includes a piston 22, which is formed as part of the rack 10 in a manner described below. The piston 22 is disposed in a cylinder 24 formed by the housing 14. The piston 22 divides the cylinder 24 into first and second fluid chambers or pressure chambers 26 and 28.

A control valve 30 is disposed in the housing 14. The control valve 30 is connected with the first and second chambers 26 and 28 of the motor 20 by a pair of conduits 32 and 34. The control valve 30 is also connected with a pump 36 and with a reservoir or sump 38, by another pair of conduits 40 and 42.

The steering system 12 further includes an input shaft 44. The input shaft 44 is connected for rotation with a steering wheel 46 of the vehicle. A torsion bar (not shown) in the control valve 30 connects the input shaft 44 with a pinion 48. The pinion 48 is in meshing engagement with the rack 16.

Upon rotation of the vehicle steering wheel 46, the torsion bar twists to enable the input shaft 44 to rotate relative to the pinion 48. Upon such relative rotation, the control valve 30 directs hydraulic fluid under pressure from the pump 36 to the motor 20. Operation of the hydraulic motor 20 moves the rack 16 and drives the pinion 48 to rotate in a follow-up manner. The control valve 30 returns to a neutral condition when the steerable wheels of the vehicle have been turned to an extent corresponding to rotation of the steering wheel 46 and the input shaft 44.

The rack 10 is formed from first and second rack parts 50 and 80 joined to each other in a manner as described below. The first rack part 50 is preferably formed as one piece, from a suitable material, such as carbon steel. The first rack part 50 may be deep drawn to the configuration shown, or could be formed in ay other suitable manner. One method for forming the first rack part 50 is described below in detail with reference to Figs. 3 and 4.

The first rack part 50 has an elongate configuration including a first end portion 52 and a second end portion 54. The first rack part 50 includes a body portion 56 and a piston portion 58.

The body portion 56 of the first rack part 50 has an elongate, cylindrical configuration centered on the axis 16. The body portion 56 has a cylindrical outer surface 60. The body portion 56 of the first rack part 50 terminates in the first end portion 52 of the first rack part.

The piston portion 58 forms the second end portion 54 of the first rack part 50. The piston portion 58 of the first rack part 50 is formed as a flange 62 extending radially outward from the cylindrical outer surface 60 of the body portion 56 of the first rack part. The flange 62

has a disk-like configuration including a circular first end surface 64 and an annular second end surface 66. The flange 62 has a cylindrical outer side surface 68. A frustoconical chamfer 70 extends between the outer side surface 68 and the first end surface 64.

An internal opening 72 extends for the entire length of the first rack part 50, between the first end portion 52 of the first rack part and the first end surface 64 of the piston portion 58 of the first rack part. In the illustrated embodiment, the opening 72 has a cylindrical configuration centered on the axis 16. The opening 72 serves as a breather hole that establishes fluid communication between the first end portion 52 and the second end portion 54 of the first rack part 50.

The second rack part 80 is similar in construction to the first rack part 50, the only significant difference being the length of the body portion. The second rack part 80 may be formed in the same manner as the first rack part 50, for example, by the method for described below in detail with reference to Figs. 3 and 4.

The second rack part 80 has an elongate configuration including a first end portion 82 and a second end portion 84. The second rack part 80 includes a body portion 86 and a piston portion 88.

The body portion 86 of the second rack part 80 has an elongate, cylindrical configuration centered on the axis 16. The body portion 86 has a cylindrical outer surface 90. The body portion 86 of the second rack part 80 terminates in the first end portion 82 of the second rack part.

The piston portion 88 forms the second end portion 84 of the second rack part 80. The piston portion 88 of the second rack part 80 is formed as a flange 92 extending radially outward from the cylindrical outer surface 90 of the body portion 86 of the second rack part. The flange 92 has a disk-like configuration including a circular first end surface 94 and an annular second end surface 96. The flange 92 has a cylindrical outer side surface 98. A frustoconical chamfer 100 extends between the outer side surface 98 and the first end surface 94.

An internal opening 102 extends for the entire length of the second rack part 80, between the first end portion 82 of the second rack part and the first end surface 94 of the piston portion 88 of the second rack part. In the illustrated embodiment, the opening 102 has a cylindrical configuration centered on the axis 16. The opening 102 serves as a breather hole that establishes fluid

communication between the first end portion 82 and the second end portion 84 of the second rack part 80.

The first rack part 50 is joined to the second rack part 80 to form the rack 10. This joining can be done in several different manners. One method is described below.

The piston portion 58 of the first rack part 50 is spin welded to the piston portion 88 of the second rack part 80. The rack parts 50 and 80 may be piloted together to keep them in alignment. The first end surface 64 of the piston portion 58 of the first rack part 50 is in abutting engagement with the first end surface 94 of the piston portion 88 of the second rack part 80. The joined piston portions 58 and 88 form the piston 22.

The body portion 56 of the first rack part 50 extends axially away from the piston 22 in a first directions indicated by the arrow 110. The body portion 86 of the second rack part 80 extends axially away from the piston 22 in a second direction as indicated by the arrow 112 opposite the first direction 110. The body portion 86 of the second rack part 80 is coaxial with the body portion 56 of the first rack part 50. The breather hole 72 in the first rack part 50 aligns with the breather hole 102 in the second rack part 80 to form a breather passage 114 extending completely through the rack 10.

The chamfers 70 and 100 adjoin to form a V-shaped groove 116 in the piston 22. The groove 116, after the spin welding process, may be at least partially filled with weld material. The outer side surface of the piston 22 is machined out to form an outer peripheral groove 118 (Fig. 1). A seal ring 120 is received in the outer peripheral groove 118 of the piston 22. The seal 120 is in sealing engagement with a cylindrical inner surface 122 of the housing 14.

When the rack, including the piston, is assembled in the housing 14, the piston is located between and partially defines the first and second pressure chambers 26 and 28 in the housing. The second end surface 66 of the piston portion 58 of the first rack part 50 forms a first end face of the piston 22. The second end face 66 is exposed to pressurized fluid in the first pressure chamber 26. The second end surface 96 of the piston portion 88 of the second rack part 80 forms a second end face of the piston 22. The second end face 96 is exposed to pressurized fluid in the second pressure chamber 28.

In operation of the steering system 12, hydraulic fluid is directed by the pump 36, in a known manner, against the first and second end faces 66 and 96 of the piston 22, to effect movement of the piston, and thereby

the rack 10, relative to the housing 14. The seal 120 seals against the cylindrical inner surface 122 of the housing 14.

Figs. 3 and 4 illustrate schematically one method of forming the first rack part 50. Other methods are usable. Because the first rack part 50 is similar to the second rack part 80, the method illustrated in Figs. 3 and 4 can also be used for forming the second rack part 80.

A cylindrical blank 130 is provided that has a central axis 131. The blank 130 is the diameter of the finished body portion 56 of the rack part 50. The blank 130 has a central opening 132 that is the same diameter as the finished breather hole 72 in the rack part 50.

A die 140 has a die cavity 148. The die cavity 148 is defined by surfaces of the die 140 including an annular, radially extending end surface 142 and a cylindrical outer side surface 144. The outer side surface 144 extends parallel to an axis 146 of the die 140, and perpendicular to the end surface 142. The die cavity 148 is larger in diameter than the blank 130. Specifically, the diameter of the die cavity 148 as defined by the diameter of the outer side surface 144 is substantially equal to the desired finished diameter of the piston portion 58 of the rack part 50.

A tubular support portion 150 of the die 140 extends from the die cavity 148 and has a central passage 152 that communicates with the die cavity. The central passage 152 is the same diameter as the blank 130. A clamp mechanism shown schematically at 154 is located adjacent or on the die 140 along the support portion 150. The clamp mechanism 154 is operative to clamp a part of the blank 130 extending through the support portion 150.

A ram or other movable forming member 160 is provided adjacent the die cavity 148. The ram 160 has a planar, radially extending end surface 162. A narrow, cylindrical pin portion 164 of the ram 160 extends axially outward from the center of the end surface 162. The pin portion 164 has the same diameter as the central opening 132 in the blank 130.

To form the rack part 50, the blank 130 is placed in the die 140. An end portion 170 of the blank 130 is located in the die cavity 148 in the die 140. The end portion 170 of the blank 130 is smaller in diameter than the die cavity 148, and is longer than the finished piston portion 58 of the rack part 50. The remainder of the blank 130 is located in the support portion 150 of the die 140, extending through the central passage 152.

The end portion 170 of the blank 130 is optionally heated as shown schematically at 172. Heating the end portion 130 can reduce the amount of working that is needed, and can limit work hardening of the metal that may occur with cold working. Otherwise, the blank 130 is cold formed to form the rack part 50.

The ram 160 is moved into engagement with the end portion 170 of the blank 130, in a direction parallel to the axes 132 and 146, as indicated by the arrow 174. The pin portion 164 of the ram 160 extends into the central opening 132 in the blank 130.

The force of the moving ram 160 is transmitted into the blank 130. The clamp mechanism 154 clamps the blank 130 and prevents axial movement of the blank. As a result, the end portion 170 of the blank 130 is deformed radially outward toward the outer side surface 144 of the die 140, and axially toward the end surface 142 of the die. The pin portion 164 of the ram 160 blocks flow of movement of the material of the end portion 170 into the central opening 132.

As the ram 160 continues to move in the direction 174, the end portion 170 of the blank 130 shortens axially and widens radially. The metal of the end portion 170 ceases flowing axially inward when it engages the end

surface 142 of the die 140. The metal of the end portion 170 ceases flowing radially outward when it engages the outer side surface 144 of the die 140. The end portion 170 of the blank 130 assumes substantially the finished shape of the piston portion 58 of the rack part 50.

After the rack part 50 is thus formed, it may be machined to finished dimensions and the chamfer 70 may be cut into it. Alternatively, the chamfer 70 may be formed, at least roughly, by surfaces on the ram 160.

From the foregoing description of the invention, those skilled in the art will perceive improvements, changes and modifications in the invention. For example, the two piston portions 58 and 88 might have different axial lengths, and the weld joining them would not be in the center of the piston 22. The seal ring groove 118 would be machined at a location other than the weld. Such improvements, changes and modifications within the skill of the art are intended to be covered by the appended claims.

Having described the invention, I claim:

1. A rack for a hydraulic power assist rack and pinion steering system for a vehicle having steerable wheels, the system including a housing in which said rack is movable along an axis to effect turning movement of the steerable wheels of the vehicle, said rack comprising:

a first rack part having an elongate body portion and an end portion formed as a first piston portion; and

a second rack part having an elongate body portion and an end portion formed as a second piston portion;

said first piston portion of said first rack part being joined to said second piston portion of said second rack part to form a piston;

said body portion of said first rack part extending axially away from said piston in a first direction;

said body portion of said second rack part extending axially away from said piston in a second direction opposite said first direction.

2. A rack as set forth in claim 1 wherein said piston has first and second opposite end faces against which hydraulic fluid is directed to effect movement of said piston, and thereby said rack, relative to said housing, said first end face being formed on said first rack part and said second end face being formed on said second rack part.

3. A rack as set forth in claim 1 wherein said piston has an outer peripheral groove for receiving a seal ring for engagement with said housing, said outer peripheral groove being formed between said first rack part and said second rack part.

4. A rack as set forth in claim 1 wherein said piston portion of said first rack part has the same axial length as said piston portion of said second rack part.

5. A rack as set forth in claim 1 wherein said body portion of said first rack part is coaxial with said body portion of said second rack part.

6. A rack as set forth in claim 1 wherein at least a portion of said body portion of said first rack part has

a smaller diameter than said piston portion of said first rack part.

7. A rack as set forth in claim 1 wherein each one of said piston portions has a respective chamfer, said chamfers adjoining when said first rack part is secured to said second rack part.

8. A rack as set forth in claim 1 wherein said first rack part is joined to said second rack part by spin welding.

9. A rack as set forth in claim 1 having a seal ring groove formed in said piston after said first rack part is joined to said second rack part.

10. A method of forming a steering gear rack comprising the steps of:

forming a first blank into a first rack part having a radially extending end portion;

forming a second blank into a second rack part having a radially extending end portion; and thereafter

attaching the radially extending portion of the first rack part to the radially extending portion of the second rack part to form an integral steering gear rack.

11. The method of claim 10 wherein said step of forming the first blank includes cold forming the first blank and said step of forming the second blank includes cold forming the second blank.

12. The method of claim 10 wherein said step of attaching the radially extending portion of the first rack part to the radially extending portion of the second rack part includes spin welding the radially extending portion of the first rack part to the radially extending portion of the second rack part.

13. The method of claim 10 wherein said step of forming a first blank into a first rack part includes forming the first rack part with an internal opening that extends the length of the first rack part, and said step of forming a second blank into a second rack part includes forming the second rack part with an internal opening that extends the length of the second rack part.

14. The method of claim 10 wherein:

said step of forming a first blank into a first rack part having a radially extending end portion includes forming a chamfer on the radially extending end portion of the first rack part,

said step of forming a second blank into a second rack part having a radially extending end portion includes forming a chamfer on the radially extending end portion of the second rack part; and

said attaching step includes forming a generally V-shaped groove in the integral steering gear rack between the radially extending end portion of the first rack part and the radially extending end portion of the second rack part when the first rack part is attached to the second rack part.

15. A method as set forth in claim 10 wherein said step of forming a first blank into a first rack part having a radially extending end portion includes the steps of:

providing a blank having an axis and an end portion with a diameter;

providing a die;

locating the end portion of the blank in the die; and

deforming the end portion of the blank against the die to form the radially extending end portion of the first blank.

16. A method as set forth in claim 10 wherein said step of providing a die includes providing a die having a die cavity with a radially outer side surface and said deforming step includes deforming the end portion of the blank against the radially outer side surface of the die to form the radially extending end portion of the first blank.

17. A method as set forth in claim 16 wherein said deforming step includes moving a ram against a radially extending end surface on the end portion of the blank to move material of the end portion axially and radially.

18. A method as set forth in claim 10 further comprising the step of heating the end portion of the blank prior to deforming the end portion of the blank.

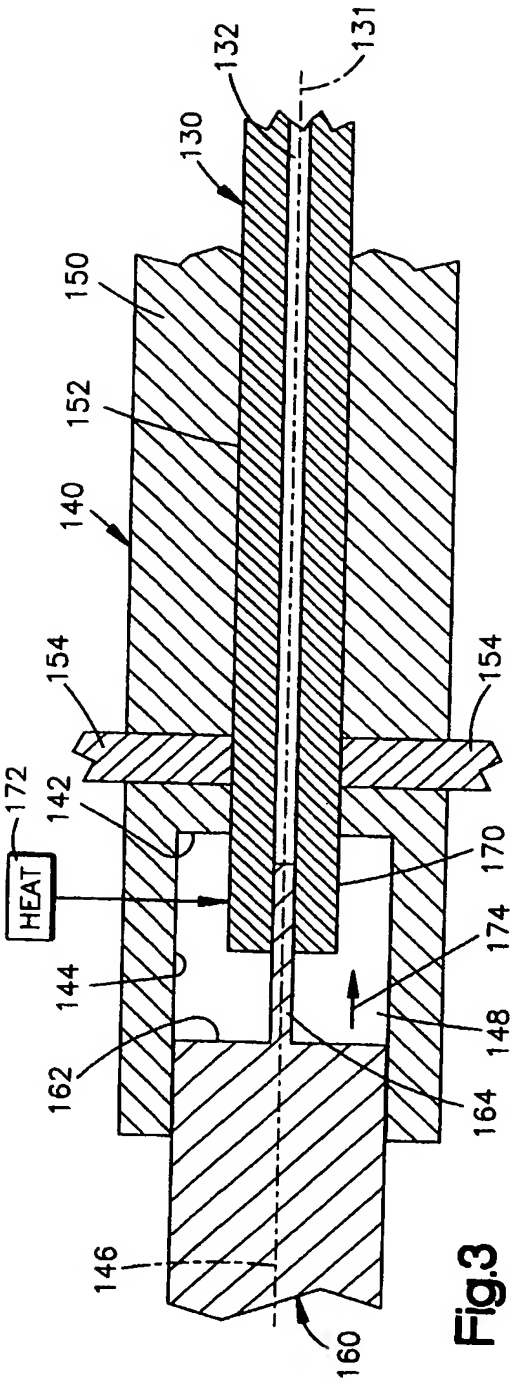

Fig.3

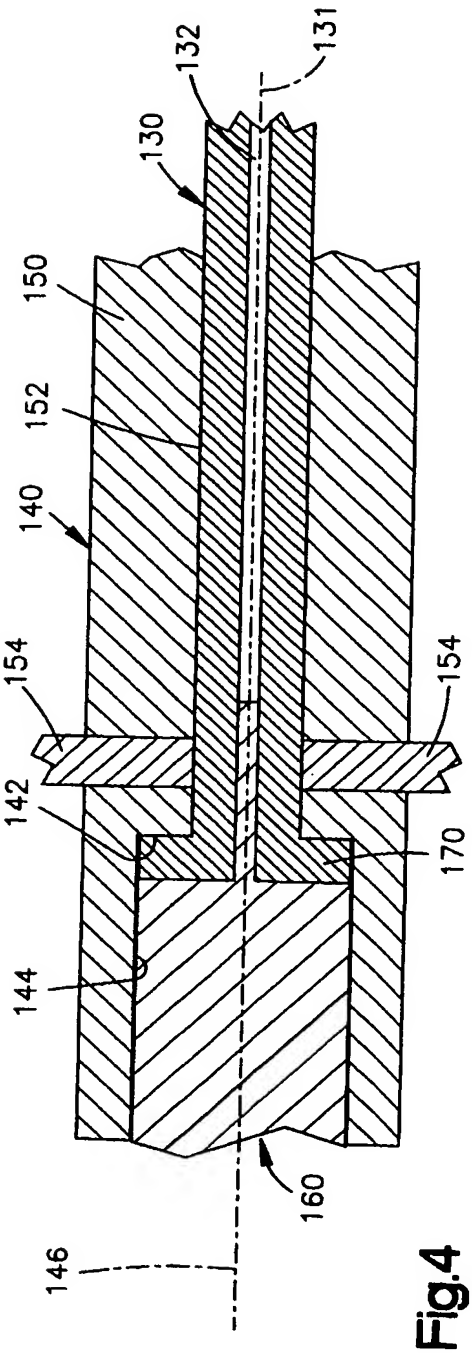

Fig.4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US02/09696

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : F16H 1/04
US CL : 074/422

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 074/422; 92/110, 172, 208, 216, 222, 231, 260, 255; 403/247,250, 263; 29/888.042,888.044

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	JP 042 94 929 A (TAKESHI) 25 March 1991, Abstract.	1, 2, 5, 6, ------ 4, 8
X	US 6,176,343 B1 (VINCENT et al.) 23 January 2001, col. 3, line 40.	10
X -- Y	US 2,574,299 A (STERRETT) 06 November 1951, col. 3, lines 1-5.	10 ---------- 12, 13

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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